1331100

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) TRANSDUCER, SUITABLE FOR USE WITH ULTRASONIC PROCESSING TANKS

(71) We, CREST ULTRASONICS CORP., having a principal place of business at Scotch Road, Trenton, New Jersey, United States of America, a corporation of New Jersey, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to transducers suitable for use with ultrasonic processing tanks.

The invention consists in a transducer suitable for application to ultrasonic processing tanks, includes: a metallic base element adapted for attachment to a radiating face of an ultrasonic cleaning tank; a metal backup element to provide mechanical loading; at least one piezoelectric element; at least one insulator element; and means connecting the several elements in superposed relation.

The present invention relates to piezoelectric transducers designed suitably to be mounted upon a radiating surface of an ultrasonic cleaning or other processing tank. The purpose of a transducer embodying the invention, when so applied to a cleaning tank, is to translate or convert an applied electrical field into a mechanical vibration in the ultrasonic frequency range and transmit this within a liquid of the cleaning tank. By a process called cavitation, highly-intensity ultrasonic wave energy is employed, responsive to electrical excitation of the transducer, which may be single or multiple, or transducers attached to the cleaning tank, for the purpose of dislodging dirt, grease, and other contaminant particles from the objects to be cleaned.

Ultrasonic cleaning apparatus embodying the invention may comprise a generator for applying an electrical voltage, the transducer to which said voltage is applied and adapted to translate the electrical voltage to vibratory energy in the ultrasonic frequency range, and a cleaning tank holding a liquid, through which liquid the ultrasonic wave energy is transmitted.

Transducers embodying the invention for purposes such as described above may be constructed as individual stacks of piezoelectric ceramic elements assembled between metal discs by means of a through bolt, and formed perhaps of a cylindrical or hexagonal configuration. The metal and piezoelectric elements of the transducers may be of like dimensions, and peripherally in registration, being bonded together when so registered and assembled, through the medium of such adhesives as one of the epoxy resins.

Another possibility is the use of an epoxy resin bond only to couple the transducer to the radiating surface of the cleaning tank, as a result of which the epoxy resin bond must provide mechanical strength in addition to acoustic coupling.

United States Patents Nos. 3,371,233 issued February 27, 1968 and 3,433,462 issued March 18, 1969, both to Edward G. Cook, relate to methods and apparatus for resonating piezoelectric crystals in a multiplicity of frequency modes and their harmonics. These patents, along with such other United States Patents as Mettler No. 3,180,626; Branson No. 2,891,176; Platzman No. 3,113,761; and Carlin No. 3,117,768 are of interest as disclosing features which may be incorporated in embodiments of the present invention. Considering the prior art generally, problems have been found in that prior art transducer constructions have not been sufficiently versatile as regards relating electrical input impedances to mechanical output impedances for generator and work load matching, respectively; have not been capable of continuous operation over a wide temperature range of zero degrees to 300°F; have not been capable of operating continuously twenty-four hours a day, seven days a week; have not been able to withstand mechanical shocks resulting from the dropping of objects into the cleaning tank,

and from rough handling during shipping; have not been able to accommodate themselves to changes such as the change of cleaning solutions; have lacked the ready capacity for field repair; have not been capable of being energized in a multiplicity of frequencies such as referred to in the Cook patents; and have permitted excessive cavitation erosion at the stainless steel radiating face of the cleaning tank.

To overcome or at least ameliorate some or all of the several deficiencies just noted with respect to prior art transducers, preferred embodiments of the invention provide transducers as illustrated and described below. These transducers include a plate-like base element of elongated parallelepiped form, having a series of threaded openings, and adapted to be attached by epoxy resin and studs or by clips to a cleaning tank; and a plurality of piezoelectric vibratory units excitable either independently or in concern. Each unit comprises a least one piezoelectric ceramic element, electrode means for exciting the same to translate an applied electrical field into a mechanical vibratory energy within the ultrasonic wave range, a metal backup plate element, a centre bolt threaded into an associated opening of the base element and passing through clearance holes in the backup and piezoelectric elements, and spring means for resiliently biasing the said elements of each unit, which are circular, into intimate face-to-face contact with one another and with the base element, while leaving them free for relative movement to accommodate the device to temperature changes and mechanical shocks The base element projects beyond the peripheries of the several units, to allow it to be clipped securely or attached by studs to the cleaning tank, and also to impart to it the characteristic of vibrating in a multiplicity of frequencies simultaneously as described in the Cook patents above. The connection of the several elements of each unit is swiftly removable, whereby to permit any one of the units to be assembled with readily substituted or interchanged elements to meet specific input or output impedance requirements.

These preferred embodiments will now be more fully described with reference to the accompanying drawing, in which:—

Figure 1 is a plan view of a transducer embodying the present invention, a cleaning tank wall to which the transducer is attached being shown fragmentarily;

Figure 2 is a sectional view substantially on line 2—2 of Figure 1;

Figure 3 is an end elevational view of the transducer as seen from the line 3—3 of Figure 2; and

Figure 4 is a fragmentary view of a modified form of transducer, partially in section, attached to the cleaning tank wall by a clip.

Referring to the drawings, a transducer, suitable for application to ultrasonic processing tanks, includes: a metallic base element 10 adapted for attachment to a radiating face W of an ultrasonic cleaning tank; a metal backup element 22 to provide mechanical loading; at least one piezoelectric element 16; at least one insulator element 20; and means 26 connecting the several elements 10, 22, 16, 20 in superposed relation. Said means 26 constitutes the sole connection between the several elements 10, 22, 16, 20 and connects the several elements together separably, whereby to permit of selectively interchanging elements such as 10, 22, 16, 20 of the transducer and thereby adjusting the electrical and mechanical impedance characteristics thereof. The means 26 connecting the several elements 10, 22, 16, 20 is a through bolt threadedly engaged at one end in one 10 of said elements and having a loose clearance fit (due to openings 30, 32, 33) through the remaining elements 22, 20, 16 and thus rendering it possible to disassemble the transducer in consequence of the removal of the bolt 26. The transducer further includes means 24 interposed between the other end of the bolt 26 and the backup element 22 and extending a resilient, yielding pressure upon the backup element 22 effective to provide a non-rigid assembly of the several elements 22, 20, 16, 14 in which each element 22, 20, 16, 14 is permitted a limited movement with respect to the next adjacent element. As seen in Figure 1, the periphery of the base element 10 is out of registration with the periphery of the or each piezoelectric element 16. The base element 10 is of a configuration with respect to the or each piezoelectric element 16 such that the periphery of the base element 10 is disposed laterally outwardly from the periphery of the or each piezoelectric element 16, providing a surface on the base element 10 exposed beyond the or each piezoelectric element 16 to receive a means 38 for connecting the transducer to the tank. Said piezoelectric element or elements 16 is or are of different configuration from that of the base element 10 and effective to resonate the base element 10 in a multiplicity of differing fundamental modes governed respectively by differing length, width, thickness, and diagonal dimensions of the base element 10, and in harmonics of these modes. The base element 10 is in the form of a plate and of parallelepiped configuration, the remaining elements 22, 20, 16 being smaller in size than and of a configuration different from that of the base element 10. The or each said piezoelectric element 16 is disposed between the base and backup elements, 10 and 22, the or each said insulator ele-

ment 20 is disposed between the or each said piezoelectric element 16 and the backup element 22 and there are electrode means 14, 18 for applying an electrical voltage to the said piezoelectric element or elements 16. The or at least one, said insulator element 20 is a piezoelectric ceramic element.

As seen in Figures 1 and 2, a multiple transducer includes a plurality (here two) of single transducers, ‹ch as just described in which a common base element 10 serves as the said base element of each of the single transducers which are arranged as independently resonant vibratory units 11 spaced apart over the surface of the common base element 10.

In the embodiment of Figure 4, the or each said insulator element 44 has a negative temperature coefficient of capacitance, and the, or at least one, said insulator element 44 is a non-polarized ceramic element.

In the embodiment of the invention illustrated in Figures 1 and 2, the transducer is shown as including a base element 10 assembled with a pair of like vibratory units generally designated 11. However, it should be noted at this point that although it is considered inventive to associate with a single base element two or more vibratory units 11, it is also believed to be within the scope of the present invention to assemble said base element with a single such unit or any number desired.

In any event, the base element 10 in the illustrated example is in the form of an elongated rectangular parallelepiped, and this has length, width, thickness and three diagonal (end, side and face) dimensions. The base element is thus resonant, as discussed in detail in Cook's United States Patent Specification No. 3,371,233, in six fundamental modes simultaneously, together with the harmonics thereof.

Base element 10 is formed with threaded through openings 12 spaced along the longitudinal centre line thereof to receive means for connecting the respective vibratory units 11 to the base element.

The units 11 are of identical construction (although they could differ in another embodiment) and accordingly, the description of one will suffice for both. Each unit 11, thus, includes at its base a first electrode 14, formed as a thin, flat, electrically conductive piece of metal. Electrode 14 could, if desired, be eliminated, in which event element 10 would be used as the first electrode. Overlying the electrode 14 is a piezoelectric element 16. This is of known ceramic composition, such as lead zirconium titanate. In the present instance, element 16 is circular, but it could be of polygonal, elliptical, or of other configuration if desired, in a typical embodiment.

An electrode 18 similar to electrode 14 is disposed between element 16 and a second piezoelectric element 20 similar to element 16 in size and configuration. Overlying element 20 is a metal backup plate in the form a block 22, peripherally registered (it is not critical that it be in registration) with elements 16, 20.

A plurality of conical spring washers 24 serving as said resilient means are stacked above plate 22, but are not always required, and an elongated connecting bolt 26 extends through concentric centre openings 28, 30, 32, 33 of washers 24, plate 22, element 20 and element 16 respectively. Electrodes 14, 18 have openings of a size the same as openings 32, 33, and are in registration with said openings 32, 33.

Bolt 26 is threadedly engaged in opening 12 of the base element 10.

No adhesive bond is provided between the several laminations of the vibratory unit 11, at the interface thereof, the several components of the unit being held in intimate contact by means of the resilient, yielding pressure exerters thereagainst through the medium of the conical spring washers 24, when the bolt 26 is through into the opening 12 to a selected, adjusted extent. As will be apparent, the pressure with which the components of the vibratory unit 11 are engaged in face-to-face contact is adjustable by turning of the bolt 26 into or out of opening 12 to whatever extent is dictated by the requirements of the particular operating environment, and, at all times, the several unit components are held securely assembled while still being able to have relative movement at their interfaces. In some instances an epoxy resin adhesive may be used between the components. Also, in some instances the conical springs may be eliminated, as noted above.

The electrodes, basically, have circular body portions preferably, but not necessarily, in registration with the circular elements 16, 20, 22, said body portions being integral with connecting tabs 34, 36 of electrodes 14, 18, respectively. The connecting tabs project radially outwardly, and are clipped to receive current conductors, not shown, whereby electrical voltage is applied to the piezoelectric elements such as 16.

Base element 10, as seen from Figures 1 and 2, projects laterally outwardly from the units 11, due to its size and shape in respect to said units, and this affords means for securely connecting the transducer to the wall W of a conventional ultrasonic cleaning tank. In the illustrated example, we have shown in Figures 1—3 one method of connecting the transducer to the wall, involving the use of attaching studs in the form of bolts 38 welded to wall W and extending through a smooth-walled opening of base element 10. In conjunction with attaching bolts

38, we also provide an epoxy resin bond 39 between the base element 10 and wall W. Nuts are threaded onto the studs, and, if desired, resilient rubber washers, may be interposed between the nuts and element 10.

In Figure 4, there is shown a modified arrangement with respect to the attachment of the transducer to wall W. In this arrangement, clips 40 are utilized, to hold the transducer against being accidentally disengaged from wall W, said clips being of any suitable form, as for example the C shape shown. Nuts 42 bear against the clips, and are threaded onto the studs 38, which extend through clearance openings provided in the clips.

Figure 4 has been utilized also to show a modified arrangement with respect to the vibratory unit. In this illustration, the vibratory unit as modified has been designated generally 11a. In place of the element 20 (or, if desired, in addition to the ceramic elements 16, 20), we have provided a flat, circular insulator element 44, further described below.

Operation

In use, a transducer formed according to the present embodiments would be attached to the wall W at any desired location. Typically, the transducers might be applied in any number to the bottom of the tanks as well as to the sides. The base element 10, in a preferred embodiment, would be of aluminium, but other metals may be advantageously used.

A calculation would be made as to the input impedance needed to match the electrical voltage applied to the vibratory units 11 by a generator, not shown. The generator might, typically, be similar to that disclosed in Cook's United States Patent Specification No. 3,371,233 issued February 27, 1968. That generator provides for resonation of a transducer in all fundamental modes and harmonics thereof, to produce, simultaneously, multifrequencies traveling throughout the tank to all areas thereof. Other generators known to the ultrasonic cleaning art can, of course, be employed if desired.

In any event, the calculations as noted above having been made, one may assemble the transducer to incorporate any of various backup elements, base elements, and piezoelectric elements available from stock, to meet a wide variety of different situations. As noted, a calculation would be made as to input impedance, for generator matching, and another calculation would be made for output impedance to match the load. The latter calculation bears upon the selection of the base element 10 and the backup plate 22 which provides appropriate mechanical loading, while the former calculation involves the selection of the shape, size and number of the piezoelectric elements.

Assuming that one has found it advisable to assemble the base element 10 with two vibratory units, as shown, the further characteristic obtains in that each vibratory unit can be independently excited, to increase still further the range of frequencies applied and hence the overall versatility of the device.

At this point, it may be noted that the provision of an elongated base element 10 of parallelepiped form not only facilitates the secure attachment of the transducer to the tank, but also provides the advantages of the simultaneous multifrequency characteristic discussed in full detail in Cook's United States Patent Specification No. 3,371,233.

Of importance also in one embodiment is the fact that no bond is provided between the several components of each vibratory unit 11. Not only does this facilitate assembly and disassembly of the unit, but also, the units are permitted relative movement, both axially and radially of the bolt 26. The results is that the several elements of the unit, especially the piezoelectric elements, will not crack under temperature changes, and at the same time there is provided maximum ease in field replacement. Although it has been proposed to provide piezoelectric ceramic elements bolted between two metal plates, typically, the metal plates have had dimensions similar to the outside dimensions of the ceramic elements, and the ceramic elements have been bonded together with epoxy resin or equivalent means. We have found that the base element 10 will vibrate in a multiplicity of frequencies and the harmonics thereof, and will fulfill completely all of the requirements for transducers as noted in Cook's United States Patents Nos. 3,371,233 and 3,433,462.

As previously noted, it is possible to stack the ceramic elements with metal electrode plates in quantities of one up to any number. It is also possible, as seen in Figure 4, to substitute an insulator element 44 for one of the ceramic element 20. A non-polarized insulator, e.g. ceramic, is preferred for the insulator element and can be chosen having a negative temperature coefficient of capacitance. As the temperature of the transducer increases during use, the capacitance of the piezoelectric element 16 will also increase. Compensation for the increase in capacitance of element 16 is provided, however, by a capacitance decrease resulting from the negative capacitance temperature characteristic of the non-polarized ceramic element 20. This, it has been found, will then provide the generator with a relatively constant static capacitance load despite temperature increases in the transducer. We have found

that this is important to insure good performance over a wide temperature range.

It has been found in an experiment that a single transducer as illustrated and described herein, can be used to overcome or amediorate all the problems noted above in prior art devices, and, as will be apparent, this has been accomplished without increase in the normal cost of a transducer. In fact, as regards the meeting of customer requirements and the adaptability for manufacture and repair of the transducer, it is believed that cost reductions can be effected even though the transducer is found to provide improved operating characteristics and maximum reliability in service.

Although the metal plates 10 are aluminium and plates 22 are steel, in a preferred embodiment, other metals may be used. Further, any number of stacks or vibratory units 11 may be employed, and within each vibratory unit any number of piezoelectric elements, according to the needs of the particular situation, may be employed.

It is also worthy of note that although the voltage is applied in the illustrated example between the centre tab or electrode 18 and effectively the base element 10, it could be applied with equally good results between electrode 18 and the top metal plate or block 22.

WHAT WE CLAIM IS:—

1. A transducer, suitable for application to ultrasonic processing tanks, including:

(a) a metallic base element adapted for attachment to a radiating face of an ultrasonic cleaning tank;
(b) a metal backup element to provide mechanical loading;
(c) at least one piezoelectric element;
(d) at least one insulator element; and
(e) means connecting the several elements in superposed relation.

2. A transducer as claimed in Claim 1, wherein said means constitutes the connection between the several elements and connects the several elements together separably, whereby to permit of selectively interchanging elements of the transducer and thereby adjusting the electrical and mechanical impedance characteristics thereof.

3. A transducer as claimed in Claim 2, wherein the means connecting the several elements is a through bolt threadedly engaged at one end in one of said elements and having a loose clearance fit through the remaining elements and thus rendering it possible to disassemble the transducer in consequence of the removal of the bolt.

4. A transducer as claimed in Claim 3, further including means interposed between the other end of the bolt and the backup element and exerting a resilient, yielding pressure upon the backup element effective to provide a non-rigid assembly of the several elements in which each element is permitted a limited movement with respect to the next adjacent element.

5. A transducer as claimed in any preceding Claim, wherein the periphery of the base element is out of registration with the periphery of the or each piezoelectric element.

6. A transducer as claimed in any preceding Claim wherein the base element is of a configuration with respect to the or each piezoelectric element such that the periphery of the base element is disposed laterally outwardly from the periphery of the or each piezoelectric element, providing a surface on the base element exposed beyond the or each piezoelectric element to receive a means for connecting the transducer to the tank.

7. A transducer as claimed in any preceding Claim, wherein said piezoelectric element or elements is or are different configuration from that of the base element and effective to resonate the base element in a multiplicity of differing fundamental modes governed respectively by differing length, width, thickness, and diagonal dimensions of the base element, and in harmonics of these modes.

8. A transducer as claimed in any preceding Claim, in which the base element is in the form of a plate and of parallelepiped configuration, the remaining elements being smaller in size than and of a configuration different from that of the base element.

9. A transducer as claimed in any preceding Claim, in which the or each said piezoelectric element is disposed between the base and backup elements, the or each said insulator element is disposed between the or each said piezoelectric element and the backup element and there are electrode means for applying an electrical voltage to the said piezoelectric element or elements.

10. A transducer as claimed in any preceding Claim in which the or each said insulator element has a negative temperature coefficient of capacitance.

11. A transducer as claimed in any one of Claims 1—9, in which the, or at least one, said insulator element is a piezoelectric element.

12. A transducer as claimed in any one of Claims 1—10, in which the, or at least one, said insulator element is a non-polarized ceramic element.

13. A multiple transducer including a plurality of single transducers, each as claimed in any preceding Claim, in which a common base element serves as the said base element of each of the single transducers which are arranged as independently resonant

1331100 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

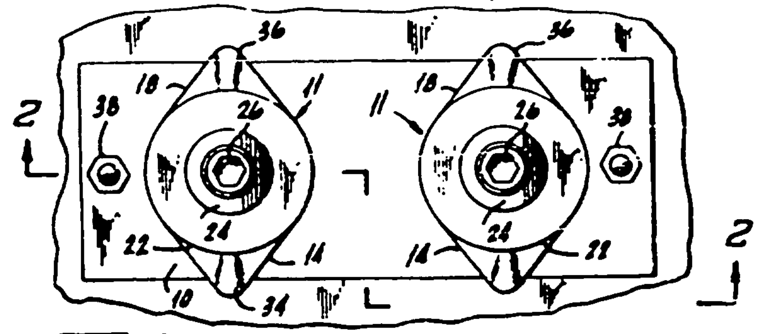

Fig. 1.

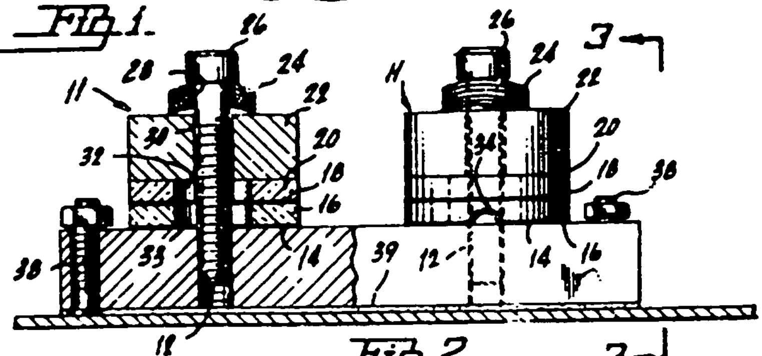

Fig. 2.

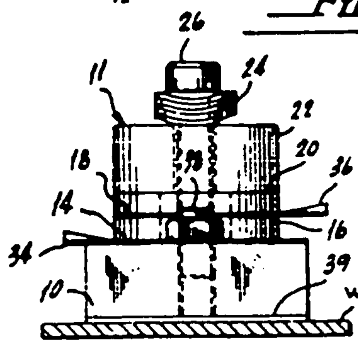

Fig. 3.

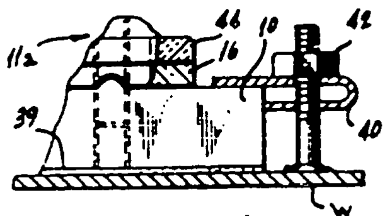

Fig. 4.